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Firms' Innovation Capability-building Paths and the Nature of Changes in Learning Mechanisms: Multiple Case-study Evidence from an Emerging Economy*

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ABSTRACT
Although much has been written about organizational-level learning, there is a dearth of empirical studies that explore the role of changes in the nature of firm-centred learning mechanisms in affecting inter-firm differences and similarities in the accumulation of innovation capabilities, especially among firms from emerging economies, known as latecomers. By examining the relationships between these issues based on fieldwork evidence from 13 natural resource-processing firms in Brazil (1950-2000s), this study found that: (1) firms that combined the use of external and internal learning mechanisms with *increased intensity and quality* achieved higher innovation capability levels than firms that used these learning mechanisms with limited frequency and unchanged quality over time; (2) the relative importance of *both* external and internal learning mechanisms changed as firms' capabilities approached world-leading levels; (3) some combinations of external and internal learning mechanisms were associated with the attainment of particular innovation capability levels. Therefore, if latecomer firms expend limited efforts in using and deliberately *changing* the intensity and, mainly, the quality of *both* external and internal learning mechanisms over time, they will deepen their innovation capabilities slowly and will remain innovation 'followers' rather than becoming world-leading innovators. Using a novel approach that explores the relationship between latecomer firms' innovation capability-building and the extent of changes in the underlying learning mechanisms, this paper furthers our understanding of the nature and dynamics of learning and its role as a primary source of firms' international innovation performance. It also challenges recent approaches that seem to over emphasize open learning processes and post-Chandlerian forms of learning as the leading sources of firms' innovation capabilities.

KEY WORDS: Innovation capability building; learning mechanisms; latecomer firms; natural resources; multiple case-study; Brazil.

JEL CODE: M1, O32, Q

*The work reported in this paper is part of a broader longitudinal study which investigated the nature, sources and outcomes of the technological capability building process in firms of the forestry, pulp and paper industries in Brazil since their inception in the 1940s up to the 2000s. The study was based on first-hand and long-term empirical evidence gathered on the basis of original and extensive fieldwork from 2005 to 2010. The study was carried out within the Research Programme on Technological Learning and Industrial Innovation in Brazil at the Getulio Vargas Foundation. We gratefully acknowledge the funding from Brazil's National Research Council (CNPq – grants 477731/2006-6 and 307404/2007-2) and from the Brazilian Pulp and Paper Association (Bracelpa). An earlier draft of this paper was presented at the DRUID Society Conference in 2010. This paper would not have been materialised without the invaluable cooperation from the professionals from the firms and from the related organizations who participated in the fieldwork for this study. All disclaimers apply.

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1. Introduction

In this paper, we examine how learning mechanisms affect differences and similarities among latecomer firms, in the same industrial sector, in building their innovation capabilities needed to achieve and sustain international competitive performance. Our interest in the impact of learning mechanisms on firms' innovation capability-building is consistent with the exponential growth of empirical studies of learning at the organizational level that has been observed since the 1990s (Shulz, 2001; Bapuji and Crossan, 2004; Taylor et al., 2011). These studies have been building on classical conceptual frameworks that were developed beginning in the 1950s (e.g., March and Simon, 1958; Cyert and March, 1963; Argyris and Schön, 1978; Levitt and March, 1988) and on previous empirical studies (see reviews in Hedberg, 1981; Fyol and Lyles, 1985; Huber, 1991; Dodgson, 1993). Despite the significant advances that have been made in existing empirical studies, there are some important shortcomings that need research attention, as we briefly review below.

Several studies have addressed learning as a source of firms' innovativeness and particularly emphasize firms' learning processes based on *external knowledge exploration*, or processes for the acquisition of new external knowledge (e.g., Katila and Ahuja, 2002; Laursen and Salter, 2006; Lane et al., 2006), together with specific approaches based on codified sources of knowledge for firms' innovativeness (e.g., David and Foray, 1995; Brusoni et al., 2005), inter-organizational relationships (e.g., Gulati, 1998; Grant and Baden-Fuller, 2004), external knowledge networks (e.g., Kale and Singh, 2007) and connectivity (e.g., Asakawa, 2002). However, a firm may acquire knowledge without *developing* the capability to undertake innovation.

In a similar vein, other studies argue that the sources of technology have become organizationally dis-integrated (e.g., Arora and Gambardella, 1994; Schmitz and Strambach, 2009). Such studies seem to reinforce the importance of external sources of knowledge for firms' innovative performance (e.g., von Hippel, 1998; Cohen and Levinthal, 1990; Chesbrough, 2006). A relatively similar perspective holds that there has been a shift from an integrated innovation and learning setting, undertaken within a multi-divisional structure, to an increasingly subdivided framework of specialized segments based on an 'open learning process' or a post-Chandlerian form of learning (Langlois, 2003). As noted in Lazonick (2010:345): "In the 2000s it can be fairly said that the Chandlerian corporation has ceased to exist." However, there seems to be little (if any) empirical substantiation to this perspective. Additionally, such a view does not consider that multi-divisional incumbents may also enhance their learning strategies to achieve long-term innovative performance (Kleinbaum and Tushman, 2007), which makes research into this issue even more timely and relevant.

Although these studies emphasize the importance of firms being open to external knowledge, internal learning processes are glossed over with a cursory reference to the importance of 'assimilating' such knowledge. Indeed, other studies have placed great emphasis on *internal knowledge exploitation,* or the reuse, expansion and application of the firm's existing knowledge to change its products and services based on sharing and coding practices (Brown and Eisenhardt, 1995; Nonaka and Takeuchi, 1995). Still more studies address the integration of internally generated knowledge with the firm's existing knowledge (Nonaka, 1994; Smith et al., 2005), or the *integration of externally acquired knowledge* with the firm's knowledge (Iansiti, 1998). Another set of studies, has developed an *integrative approach* to learning by realising the importance of combining internal and external knowledge (Hargadon and Sutton, 1997; Lichtenthaler and Lichtenthaler, 2009).

It is undeniable that the abovementioned studies have yielded relevant analyses of the importance of learning, from different perspectives, to the innovativeness of firms. However, these studies are almost entirely about managing learning in highly innovative and world-leading firms in advanced economies – where most or all elements of the capabilities for innovation already exist – not about how firms manage the process of *creating* those capabilities in the first place. Specifically, one of the major problems in these studies of learning is that they devote little, if any, attention to the learning processes that permit firms to *create* and accumulate their current innovation capabilities. This is a critical issue for *latecomer firms*. Being in a historically determined, rather than strategically chosen, position of late entrance (Mathews, 2002), latecomer firms are normally characterized as having a low level or even an absence of innovation capabilities and being 'initially imitative' (Bell and Figueiredo, 2012). To compete in global markets, latecomer firms first need to engage in deliberate and painstaking technological learning processes to *develop* innovation capabilities that will permit them to catch up with and even overtake world-leading incumbents (Malerba, 1992; Lall, 1992; Bell and Pavitt, 1993; Kim, 1997, 1998). Therefore, understanding the nature and dynamics of this learning process helps explain why latecomer firms succeed or fail in catching up with global leaders.

Consequently, the studies of learning centred on innovative firms in advanced economies contribute very little to the understanding of learning in *latecomer firms*. First, the studies focus on what firms know today and how they explore, exploit, and renew their innovation capabilities to help advance the technological frontier. Second, most of the studies are based on cross-sectional designs and econometric analyses, that is, on a static methodological approach that obscures the *changes* in learning processes over time. Such a shortage of dynamic and process-oriented empirical analyses of learning affects not only the understanding of learning in latecomers but has also been considered a limitation, even in the organizational learning literature in advanced economies (Argote and Miron-Spektor, 2011), although there are exceptions (e.g., Tell, 2002; Enberg et al., 2006).

Nevertheless, some studies of learning in innovative firms in advanced economies have offered insights to studies of learning for innovation capability building in latecomer firms, especially since the 1990s. One notable contribution is Kim (1997; 1998). By studying the catching-up process in South Korea, he showed, for example, how Hyundai organized its learning process in a circular sequence of four steps: (i) internal preparation for the acquisition of external knowledge, (ii) the acquisition of that knowledge, (iii) effective assimilation of that knowledge, and (iv) subsequent improvement, creating a wider knowledge base for the preparatory phase of another cycle of learning. Although access to external knowledge and skills was a key issue for capability development, three of the four steps in each cycle focused on internal learning efforts that played two key roles in complementing external knowledge acquisition in the overall learning process: creating, *ex ante*, the necessary knowledge base for acquiring external technology, and not merely ensuring, *ex post*, the effective absorption of whatever knowledge had been acquired externally (Bell and Figueiredo, 2012).

Subsequent studies addressed the *integration* of different forms of knowledge and capability in firms from other emerging economies, focusing on, for example: knowledge in different parts of the organization in the analysis of a single firm in Mexico (Dutrènit, 2000); the examination of capabilities created by different learning mechanisms in two Brazilian steel firms(Figueiredo, 2003); and people-embodied and disembodied capabilities in a study of technological learning in 26 telecommunications firms in four African countries (Marcelle, 2004).

Despite these contributions addressing latecomer firms, and notwithstanding the profusion of studies of learning in the literatures of organizational learning and strategic management since the 1990s, the understanding of the role of learning in innovation capability-building paths pursued by latecomer firms remains relatively incipient. Specifically, there is scant literature on the systematic analysis of the ways in which latecomer firms manage the kinds of learning mechanisms that may affect their innovation capability-building paths. Therefore, by building on the existing empirical contributions, this paper addresses the relationship between latecomer firms' innovation capability-building paths and the nature of changes in the underlying learning mechanisms. Specifically, to investigate this relationship between capability building and learning, this paper is structured around this central research question: To what extent does the degree of changes in the incidence and quality of learning mechanisms affect differences and similarities among latecomer firms, of the same industrial sector, in the building of innovation capabilities? We examine this research question based on long-term and first-hand evidence derived from extensive fieldwork in a set of natural resource-processing firms in Brazil during the period 1950s-2000s.

The remainder of this paper is organized as follows. Section 2 presents the paper's conceptual framework, while Section 3 contains the empirical context and the study's methodology. Section 4 presents the empirical findings followed by discussions and theoretical implications in Section 5. Implications for corporate management are outlined in Section 6 followed by the paper's conclusions in Section 7.

2. Conceptual Framework

This section provides the conceptual foundation for the examination of this paper's research question. We begin with a conceptual approach to latecomer firms' innovation capability-building and the role of the underlying mechanisms. Then, we demonstrate how these concepts are operationalized to achieve solid construct validity.

2.1 Pathways pursued by latecomer firms in the accumulation of innovation capabilities

Firms' capabilities include a stock of resources that permit them to undertake *production* and *differing degrees* of innovation activities. Such capabilities both involve the nature of human capital (e.g., specialist professionals, knowledge bases and skills/talents that are formally and informally allocated within specific organizational units, projects and teams) and organizational aspects (the firms' internal and external organizational arrangements, such as their routines and procedures, and managerial systems (e.g., Bell and Pavitt, 1993; Leonard-Barton, 1995;Kim, 1997;Dutrénit, 2000;Teece, 2007). In line with previous relevant studies (Bell and Pavitt, 1993, 1995; Choung et al., 2006), this paper distinguishes between *production-based* and *innovation* capabilities and focuses on the development of the latter capability.

In this paper, the notion of innovation capability development (technological catch-up) reflects a narrowing of the gap among firms in their capability to undertake *innovative* activities or, in other words, a closing of the gap between a firm and the innovation 'frontier'. In contrast to common views of 'catch-up' that suggest a single pathway along which firms seeking to reach a technological frontier (which is defined as an end-point or even a moving target previously defined by global incumbents) are distributed, this paper considers a technological frontier to be a fluid area or horizon to be explored, and the notion of catch-up herein also encompasses so-called 'overtaking' (Bell and Figueiredo, 2012).

Thus, just as new entrants and even incumbents from advanced economies may challenge existing global leaders by engaging in disruptive innovations (Christensen, 1997), latecomer firms may do so by accumulating world-leading innovative capabilities and creating new technological segments in the technological frontier. With these technological segments, they may pursue significantly new innovation *directions* that depart from the trajectories previously mapped by earlier innovators, thus introducing *qualitatively different segments* in the international innovation frontier (Bell and Figueiredo, 2012).

2.2 The role of learning in building innovation capability in latecomer firms

Over the past decades, 'learning' has been defined in various ways in different research streams. For instance, in advanced economies, one of the most influential examples is by Cohen and Levinthal (1990),who identify the 'two faces' of R&D: one concerned with generating new knowledge for innovation *inside* the firm and the other with acquiring existing knowledge from outside the firm. These authors identify the latter as learning. In some research streams in developing and emerging economies, learning is understood as a *particular kind of knowledge* or a mechanism to acquire knowledge from external sources—usually meaning external to the local economy as well as to the technology-using firm—rather than knowledge acquired via internal knowledge-creation activities (Amsden, 1989; Viotti 2002).

Instead, consistent with the literature on latecomer technological learning (Bell, 1984; Malerba, 1992; Bell and Pavitt, 1993; Kim, 1997, 1998) in this paper, we define learning as a costly and deliberate*process* by which additional technical skills and knowledge are acquired by individuals and by the firm. This process is cumulative and increases firms' stock of knowledge (or capabilities), which, in turn, permits firms to undertake innovation activities. The factors that are most appropriate for explaining the nature of the accumulation of innovative capabilities are those related to the specific investments that firms make to *create* those capabilities. We refer to those investments as 'learning', and to reiterate, we use that term to mean the process of *creating* the ability to innovate, not a particular kind of innovative activity.

Therefore, we adopt a comprehensive approach to learning that encompasses all ways in which firms may acquire knowledge, skills and other cognitive resources needed to engage in innovative activity. Specifically, in connection with Cohen and Levinthal (1990) and Malerba (1992), learning herein refers to different sources of knowledge that are internal and external to the firm; it covers both external sourcing and internal knowledge creation by several mechanisms, including R&D. This approach is largely consistent with what is used in the latecomer technological learning literature (Lall, 1992; Bell and Pavitt, 1993, 1995; Kim, 1997, 1998; Mathews and Cho, 1999; Dutrénit, 2000; Figueiredo, 2003; Marcelle, 2004; Mytelka, 2006; Dantas and Bell, 2009).

The importance of integrating internal and external learning has been discussed in some studiesthat focus on firms in advanced economies, as referred to earlier. Cohen and Levinthal (1990) argue that a firm's absorptive capacity depends on the structure of communication between the external environment and the nature and distribution of expertise within the organization. Specifically, the process of internal knowledge absorption and the formation of capabilities have been studied as different types of 'combinative capabilities' (Kogut and Zander, 1992; Van den Bosch et al., 1999), 'knowledge sharing' (Leonard-Barton, 1995), 'integration' (Grant, 1996), and organizational routines, experience accumulation, and knowledge articulation and codification (Nonaka, 1994; Nonaka and Takeuchi, 1995; Zollo and Winter, 2002).

The degree of difficulty and quality of learning increase according to the relevant characteristics of knowledge to be acquired and assimilated, for instance, the extent to which external knowledge is targetted to the firms' specific needs (e.g., input from suppliers) or less-targetted (e.g., links with universities) (see Cohen and Levinthal, 1990). Even higher learning and cognitive efforts are necessary as the firm seeks to internalize the externally acquired knowledge (e.g., through codification) (see Zollo and Winter, 2002). However, we know little about how the nature and quality of learning mechanisms change as firms increase their innovation capabilities over time.

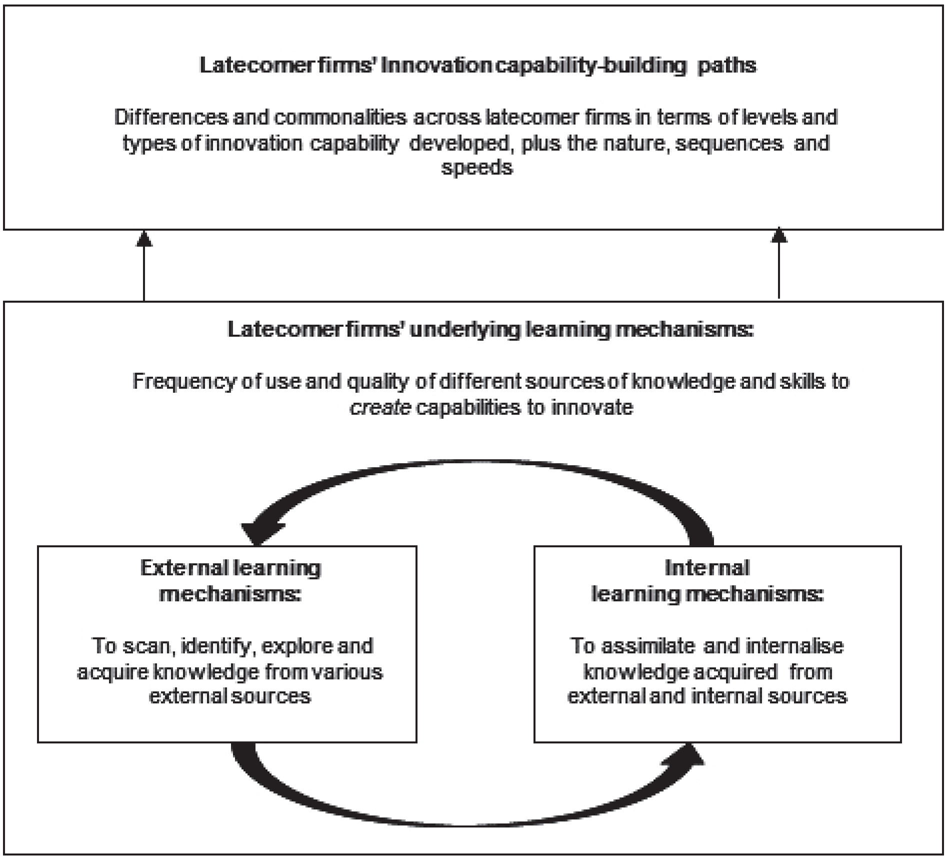
Nevertheless, the literature of technological learning in latecomer firms offers some insights. For instance, studies of innovative capability development have frequently emphasized the importance of learning mechanisms such as 'learning by hiring' and various kinds of training for the development of design and engineering capabilities or 'project execution capabilities' (see Enos and Park, 1988; Dantas and Bell, 2009). This is consistent with Malerba's (1992) idea that "because there are several sources of knowledge, the type of learning highly affects the type of stock of knowledge [capabilities] that firms have". This idea seems to imply that changes in the types of learning are needed if firms pursue the development ofincreasingly sophisticated and innovative stocks of knowledge. Again, there is scant empirical analysis of the implications of changes in the nature of learning for firms' innovation capability-building.

Additionally, because we study learning as a *process*, we reject the punctuated and dichotomic approaches to learning, such as 'single-loop *vs*. double-loop learning' (Argyris and Schön, 1978), 'adaptative *vs*. generative learning' (Senge, 1990), and 'tactical *vs*. strategic learning' (Dodgson, 1991). Therefore, by adopting a process perspective, we are interested in how learning unfolds through sequences over time (March and Olsen, 1975; Huber, 1991; Dixon, 1992; Argote and Miron-Spektor, 2011) and how learning changes over time; that is, we are concerned with the *dynamics* of learning (Berends and Lammers, 2010; Enberg et al., 2006). When understood as a *process*, learning is consequently subject to discontinuities, breakdowns and interruptions (BertoinAntal et al., 2001; Bontis et al., 2002; Engeström et al., 2007).

In addition, as noted in Elkjaer (2001) and Tosey (2005) there tends to be an emphasis on optimistic perspectives on learning, implying that it always produces positive results. However, we argue that when learning is ineffectively managed, it may lead to negative outcomes in building innovation capability (Bell et al., 1982; Bell, 1984; Dutrénit, 2000; Figueiredo, 2003). Indeed, we know little about whether and how learning may influence differences and commonalities among firms, operating in similar industrial sectors, in building innovation capability.

By drawing on the above studies, we argue that both the quality of the learning mechanisms and how frequently they are used by latecomer firms affect differences and commonalities in the way in which they *develop* technological capabilities to undertake innovation activities. These issues constitute the primary components of the conceptual framework of this paper (Figure 1). The framework in Figure 1 depicts the relationship between firms' innovation capability development and the underlying learning mechanisms. Specifically, learning is depicted as an on-going and interactive process involving external and internal learning mechanisms whose changing intensity and quality explain the differences and commonalities in innovation capability-building paths of latecomer firms. The remainder of this section outlines how the constructs that underpin the analytical framework and questions are operationalized.

Figure 1.Firms' innovation capability building and the underlying learning mechanisms



2.3 Operationalising the constructs

2.3.1 Innovation capability building in latecomer firms

In the operationalization of the capability-building construct over the past few decades in advanced economies, the assessment of innovation capabilities has been heavily based on quantitative measures such as R&D expenditures and patent citations (Hagedoorn and Cloodt, 2003). Although it has been recognized that such measures have limitations as proxy indicators of innovative activity (Teece, 2007), they have been widely used in the innovation literature. However, such indicators reflect situations in which a significant amount of innovative capability already exists. Such measures thus reveal little about the earlier process of developing and accumulating capabilities up to the point at which they begin to generate measurable R&D activities or officially recorded patenting. These measures are not suitable for capturing data on the process by which latecomer firms create and accumulate their innovation capabilities(Bell, 2006;Bell and Pavitt, 1993; Lall, 1992). Addressing such a *process* is crucial for the understanding of innovation capability-building in latecomer firms, as referred to in Section 1.

Consequently, in this paper, we adopt an approach that has been the primary basis of research in this area since the earliest studies of the innovation capabilities of latecomer firms (Katz, 1987; Bell et al, 1982; Lall, 1987; 1992; Bell and Pavitt, 1995). This approach involves the direct acquisition of descriptive information on firms' technological *activities*. Differences in the qualitative characteristics of these activities have been deemed to reflect differing categories of underlying technological capabilities. Specifically, this paper draws on a modified version of the typology developed in Lall (1992) and further refined in Bell and Pavitt (1995). The modified version of this typology identifies 'levels' of innovative capability that range from 'basic' to 'world-leading' and are consistent with the characterization of innovation as *degrees of novelty* ('new to the firm', 'new to the economy' and 'new to the world') and complexity in technological activities; thus, these levels are consistent with the Oslo Manual (see OECD, 2005).

Such a typology has been used intensively and successfully in studies, with different degrees of capability-level disaggregation that have reconstructed historical paths of capability building over considerable time periods (e.g., Dutrénit, 2000; Figueiredo, 2002, 2010; Dantas and Bell, 2009). This typology has also been used in studies that have covered the histories of capability building in a much larger number of firms, although usually over shorter periods (e.g., Hobday et al., 2004; Tsekouras, 2006; Iammarino et al., 2008; Ariffin and Figueiredo, 2004; Ariffin, 2010; Yoruk, 2011; Figueiredo, 2011; Perally and Cantwell, 2012). Rather than identifying capabilities in terms of the specific resources entailed therein, these works have identified levels of innovative *activities* and then inferred the various levels of capability that permit firms to undertake such innovative activities. The focus on *activity* is in itself a reflection of a concern with the *dynamics* of capability building. A summary of the typology tailored for use in this study is provided in Table 1. The first column shows four levels of innovative capability that extend from 'basic' to 'world leading'; the second column provides illustrative examples of activities that reflect these levels of capability.

Table 1.Typology to assess firms' innovation capabilities

Levels of innovation capabilities	Illustrative examples of activities that express these capability levels
World leading (frontier pushing)	Being able to undertake cutting-edge innovation that provides the firm with a world-leading technological and market position (e.g., R&D for the introduction of new-to-the-world forestry development processes along new technological trajectories based on R&D in genomics and proteomics; playing leading roles in world-leading research networks; development of new production processes based on R&D and engineering; intellectual property system).
Advanced	Being able to close in on global leaders in terms of introducing innovations based on fast-follower kind of strategy thus achieving a competitive position in local and export markets, but not as leader (e.g., R&D projects for the introduction of new feedstock processes implemented by innovation leaders).
Intermediate	Being able to implement of relatively complex modifications to forestry techniques and to pulp and paper making processes and products. These permit the firm to achieve and sustain a competitive performance within the local national or niche markets.
Basic	Being able to implement innovative activities which are novel to the firm and allow the firm to sustain a competitive performance in a regional market

Although the above framework emphasizes those capabilities that are internal to the firm, it also recognizes that a substantial part of a firm's capability to innovate is grounded in the activities of other organizations (e.g., consulting firms, research institutes, and universities). Consequently, the development of innovation capability is not necessarily confined within the boundaries of a firm but may instead involve several interdependent actors. However, for the firm to access such a breadth of knowledge, it must develop a substantial level of in-house expertise and a demand for local R&D outputs (Mowery, 1983) or absorptive capacity (Cohen and Levinthal, 1990). Such an approach is particularly appropriate when latecomer firms engage in the development of innovation capability, as examined herein.

2.3.2 Learning as source of innovation capability in latecomer firms

Learning in this paper is operationalized through various mechanisms that firms may use to acquire different types of technical knowledge from external sources and assimilate these types of knowledge internally to develop their innovation capabilities. In other words, learning mechanisms herein involve the acquisition of knowledge from diverse external sources as well as internal knowledge creation. Through learning mechanisms firms may acquire the tacit and codified dimension of knowledge or knowledge in disembodied and embodied forms (e.g., people and human capital). The typology in Table 2 was developed in this study to examine the external and internal learning mechanisms underpinning firms' paths to building innovation capability. An expanded version of this framework is presented in Appendix. These typologies were constructed by combining approaches and examples from different streams of literatures with the empirical evidence derived from fieldwork, as we will refer to in Section 3.

Table 2. Framework for examining learning mechanisms

	Types of learning mechanism	Codes
External learning mechanisms (ELM)	Hiring of expertise	ELM-1
	Local education and training programmes	ELM-2
	International education and training programmes	ELM-3
	Organizational arrangements for external knowledge acquisition	ELM-4
	Learning from technical assistance and specialized consulting firms	ELM-5
	Acquisition of codified knowledge as a basis for different innovative activities	ELM-6
	Training with local and foreign suppliers	ELM-7
	Knowledge-based interaction with leading users	ELM-8
	R&D-based interactions with competitors	ELM-9
	R&D-based interactions with local universities and research institutes	ELM-10
	R&D-based interaction with international universities and research institutes	ELM-11
Internal learning mechanisms (ILM)	Various kinds of training to acquire and disseminate innovation related-skills	ILM-1
	Knowledge articulation and various kinds of intra-firm communication	ILM-2
	Knowledge sharing various forms of knowledge acquisition within the firm	ILM-3
	Knowledge codification and related organizational arrangements	ILM-4

3. Empirical Context and Methodology

3.1 Empirical context

The study reported here is centred on natural resource-based industries located in an emerging economy, namely the pulp and paper industries based on eucalyptus forestry. The pulp and paper industries are highly intensive in capital, processes and scale, while forestry itself is increasingly knowledge-based. The paper-making process involves the conversion of wood chips into pulp, which is processed to create paper. Pulp, the primary raw material used in papermaking, is obtained from trees such as pine (long-fibre) or eucalyptus (short-fibre). Planted forests are renewable resources for diverse industries based on raw materials from fibres and lignocelluloses, particularly the pulp and paper industries. To achieve and sustain a global competitive position in this industry, firms must master innovation capabilities *near* or *at* a world-leading level, especially in forestry research in the development of new genetic material.

In 2010, Brazil ranked as the world’s fourth-largest pulp producer (all types), the largest producer of eucalyptus pulp (‘eucapulp’), and the ninth-largest paper producer. All pulp and paper produced in Brazil is derived from planted forests. Although the pulp and paper industries in Brazil consist of more than 200 firms, nearly 90 per cent of the total output comes from approximately 12 large firms. Over the past years, Brazil has held a stronger leading market position in these industries, largely because of the innovations implemented by some leading firms, especially in eucalyptus forestry (Evans and Turnbull, 2004). From 1970 to 2009, Brazil's annual exports of pulp and paper increased, on average, by 14.2 per cent and 22.3 per cent, respectively, while the average growth rates of Norscan countries (Canada, the U.S., and the Scandinavian countries, Sweden, Finland, and Norway) were 0.18 per cent (pulp) and 2.1 per cent (paper) during that period (see www.faostat.fao.org)

3.2 Methodology

To answer the paper's research question, the design of this paper is based on a process approach, longitudinal evidence covering decades, and an in-depth case study involving firms of a similar industrial sector; thus, its design is consistent with Pettigrew (1990) and Van de Ven and Poole (2005). Such a research strategy is appropriate for addressing the issues raised by the paper's research question because it facilitates the understanding of what lies behind a subtle and under-researched phenomenon whose details and nuances would not be captured by other methods, especially aggregated analysis derived from purely quantitative methods (Eisenhardt, 1989; Strauss and Corbin, 1998; Yin, 2003). The original study underpinning this paper sought to examine the process of innovation capability-building, the underlying learning strategies and their implications for competitiveness in latecomer natural resource-processing industries, focusing on the pulp and paper industry in Brazil. This empirical study involved a four-year fieldwork campaign (2006-2009, with a follow-up in 2010) and an intense triangulation of data-gathering techniques involving exploratory, pilot, and main fieldwork phases. Below, we outline additional aspects of the research design and methods.

3.2.1 Cases selection

We selected information-rich cases from which we could learn a great deal about issues of central importance to the purpose of the research (Patton, 1990) and that provide powerful examples of the phenomenon under study (Siggelkow, 2007), including polar cases (Eisenhardt, 1989). The longitudinal design combined with a theoretical sampling approach permitted us to gather comparative evidence of changing learning mechanisms over time with different implications for similarities and differences among the case firms. Additionally, the cases were selected using the following criteria: (i) the firms account for nearly 85 per cent of the pulp and paper output in Brazil; (ii) they are large exporters and domestic market suppliers; (iii) some of them are top players in the world market; and (iv) they illustrate different levels of capability building and varied learning processes. Therefore, we have selected 13 firms. From these firms, we chose seven cases in forestry, nine in pulp, and 11 in paper (see Table 3).These numbers permitted us to conduct the research without amassing an unmanageable volume of information (Eisenhardt, 1989).

Table 3. The selected multiple cases

Firms	Initial year of coverage in the study	Business lines		
		Forestry [7]	Pulp [9]	Paper [11]
1. Delta	1945	✓	✓	✓
2. Theta	1974	✓	✓	✓
3. Kappa	1941	✓	✓	✓
4. Zeta-A	1990	✓	✓	✓
5. Sigma-A	1988	✓	✓	✓
6. Alpha	1978	✓	✓	None
7. Beta	1975	✓	✓	None
8.Gamma	1990	None	✓	✓
9. Sigma-B [(a)]	1988	None	✓	✓
10. Epsilon	1990	None	None	✓
11. Zeta-B	1985	None	None	✓
12. Iota	1978	None	None	✓
13. Lambda	1966	None	None	✓

Note: (a) Sigma-B does have forestry operations, but this business was not included in this study.

3.2.2 Evidence gathering process

We began by contacting the top-ranked director of each firm to clarify the purpose of our research and to establish its legitimacy. Their approval allowed us to tap into various sources of information (e.g., industrial directors, managers, engineers, researchers, technicians, consultants, human resources and engineering departments, R&D units, labs, shop-floors, retired staff and archival records). We used a triangulation approach to evidence gathering to achieve robust internal validity and reliability (Jick, 1979; Eisenhardt, 1989; Yin, 2003). Specifically, we used intensive open-ended interviews, with other evidence-collection techniques to reduce recall error, to reconstruct the historical paths of capability accumulation and to explore the changing nature of the underlying learning mechanisms over considerable time periods. Thus, during the pilot and main fieldwork, our data collection involved 155formal interviews (from one to three hours each),44 informal interviews, 19 direct observations, and several consultations of archival records. Eleven formal interviews and 15 archival consultations were made at industry-related organizations (e.g., industry associations, consulting firms, suppliers, universities and research institutes).

To conduct the initial interviews, we created an interview guide which was first used during the pilot work. This interview guide was constructed according to our analytical framework, constructs, and typologies. Based on the experience and the evidence gathered during the pilot phase, we improved the interview guide to be applied during the main fieldwork. Each interview was conducted by two researchers on the basis of a structured but inductive conversation. This procedure permitted us to apply the interview guide effectively, undertake joint note-takings, filter the interviewees' responses, identify and discuss components of constructs that emerged during interviews, undertake joint-interpretation and discussions of evidence during de-briefing sessions and the transcription processes. Additionally, the combination between the evidence that emerged from these field interviews and available frameworks and insights from the literatures related to learning permitted us to construct the typology of learning mechanisms outlined in Table 2 and the Appendix.

Because the aim of this study was to examine historical changes in firms' capability accumulation and the underlying learning mechanisms, particular efforts were made to collect sufficient data to substantiate the reconstruction of the technological pathways followed by each firm. This was undertaken by scrutinising the firms' technological milestones provided by different interviewees (including retired staff), internal presentations and records, annual reports and independent news reports. Double- and triple-checks of specific events were made via e-mail and/or phone calls. Even so, it was difficult to obtain a completely accurate history. This is one of the limitations of this study. Nevertheless, the extensive use of triangulation allowed us to gather evidence from a range of sources to substantiate the results of our analysis.

After the main fieldwork, 259 follow-up questionnaires were sent to target informants within the researched firms. Because most of them had met the researchers during the fieldwork, a 95 per cent response rate was achieved. The purpose of the questionnaire was to expand the findings and, in particular, to systematize and code the evidence of external and internal learning mechanisms used by the case firms during the period under study. The questionnaire involved a matrix type of form derived from the framework in Table 2 and Appendix. The questionnaire was also shaped by the first-hand evidence gathered during fieldwork. The rows contained a detailed list of potential external and internal learning mechanisms that the firms could have used; the columns referred to each year of the period covered by the study and the year in which each learning mechanism was used. In the cells the respondents wrote examples of the benefits of these learning mechanisms for the building of innovation capability in the firm.

Each event reported in the questionnaire was counted as one learning mechanism used, which allowed us to assess changes in the use of each learning mechanism over time. Using this procedure, we captured 3,774 observations of learning mechanisms. This procedure permitted the identification of several types of external and internal learning mechanisms that were included in this questionnaire. The use of this questionnaire permitted the evidence to be numerically coded to perform statistical tests. Additionally, qualitative evidence was used to enrich the interpretation of the quantitative analysis derived from these statistical tests, and vice versa.

3.2.3 Analysis process

The analysis process began during the fieldwork. As we conducted the field interviews, we made associations between the ways in which each firm used its learning mechanisms and accumulated its innovation capabilities over time. Such insights, together with the interview transcripts, were debriefied daily among the researchers as a first step in the analysis process.Formal analyses involved the following techniques: (i) harmonization and combination of the evidence from the interviews and observations with those from the follow-up questionnaires; (ii) tabulation of the frequencies and types of observations *over time* and construction of systematic and successive 'cross-company display tables' based on a 'data reduction' procedure (Miles and Huberman, 1994), which was used to reduce the sheer volume of informationto a manageable size and to track the main stages in the study's constructs in a coherent manner; and (iii) systematic matching of different pieces of evidence from the cases with the study's conceptual framework to achieve solid construct validity (Campbell, 1975).

Additionally, rather than reducing all qualitative data to quantitative observations, both types of evidence were used to form the study's dataset, to perform several statistical tests and to enrich the empirical analysis. For instance, qualitative evidence from the application of the capability framework (Table 1) was transformed into quantitative observations and aggregated into a single index to represent the overall capability level of each firm in the three business lines (forestry, pulp and paper) over time. The learning mechanisms outlined in the Appendix were coded and aggregated into the categories of Table 2 to test statistically their intensity, quality and their association with capability building. Finally, the qualitative evidence described in Section 4 in the form of narratives, contributes to both strengthening the arguments and establishing causal relationships (Dougherty, 2002).

4. Findings

This section presents the main empirical findings and discussions using the framework described in Section 2. Section 4.1briefly describes the paths of innovation capability-building pursued by the studied firms (1950-2010). Section 4.2 presents our findings on the role of the learning mechanisms underlying these capability-building paths.

4.1 Paths of innovation capability building taken by the researched firms

Historically, the world’s main producers and innovators in the forestry, pulp and paper industries have been the Norscan countries. However, the findings indicate that in the 1960s and 1970s, a major breakthrough in eucalyptus-based forestry technology was achieved, particularly in Brazil(see Figueiredo, 2010; Grattapaglia and Kirst, 2008).Leading firms such as Kappa began to diverge from the existing technological trajectory at an *early stage* of the development of their innovation capabilities. Just after World War II, these firms began to produce pulp and paper from eucalyptus trees and to engage in activities in which firms in the Norscan countries were not engaged.

This development indicated that at a relatively early point, these firms could not simply copy the recognized global leaders and were instead forced to develop technologies more suited to their own unique operations. These firms could not simply *imitate* because they were developing along a different trajectory. This new trajectory involved the use of different raw materials (eucapulp) and the development of an effective means of using this material. Consequently, the Brazilian firms had to create downstream pulp and papermaking processes because of the innovations that emerged in upstream forestry.

The experience of leading firms in Brazil's pulp and paper industries provides an example of seizing an opportunity to undertake world-leading innovation and achieving international leadership. Until the mid-1960s, paper produced by the world's leading firms in the Norscan countries was produced from long-fibre pulp derived from conifers. These leading incumbents continued to develop along this technological trajectory, but as early as the 1960s, several paper producers in Brazil shifted to production based on short-fibre pulp derived from eucalyptus, a source of pulp with great potential in Brazil that is compatible with Brazil's environmental conditions. This innovation involved the original development of new eucalyptus varieties that were more productive and more resistant to disease. In parallel, this innovation involved the development of a modified process technology that was installed in a succession of new plants over three decades. Specifically, the firms embraced a *different direction* of technological development from that of the global industry leaders. By doing so, these firms introduced a qualitatively different segment at the international technological frontier. By engaging in original R&D based on advanced biotechnology methods and nanotechnology (since the 1990s), the leading firms established worldwide leadership in what has become a new, technologically differentiated segment of the global paper industry.

This pathway contrasts with the majority of case studies reported in the related literature: it involved a *qualitative discontinuity* from the established technological trajectory at an *early stage* in the development of the firms' capabilities. As shown in Table 4, some firms achieved world-leading innovation capability level at a relatively fast pace (e.g., Alpha, Sigma-A, Sigma-

B), while others achieved that capability level more slowly (e.g., Delta, Kappa). At this technological position, these firms are able to push the international innovation frontier forward by developing innovation capabilities at world-leading levels; thus, they have been able to undertake innovative activities with a 'new-to-the-world' degree of novelty.

Table 4. Levels of innovation capability accumulated by the case firms

Levels of innovation capability	Business lines and firms		
	Forestry	Pulp	Paper
World leading	Sigma-A	Sigma-B	Sigma-B
	Alpha	Sigma-A	Sigma-A
	Delta	Alpha	Delta
	Theta	Delta	Kappa
	Kappa	Kappa	
Advanced	Beta	Gamma	Theta
		Beta	Gamma
			Zeta-B
Intermediate	Zeta-A	Zeta-A	Zeta-A
		Theta	Epsilon
			Iota
			Lambda

Source: Derived from the empirical study.

In comparison, other firms achieved a 'follower-type' of innovation capability level (e.g., Beta Gamma-pulp) or reached levels that were halfway to the innovation frontier (e.g., Zeta-A, Theta-pulp). Others had their innovation capability-building paths interrupted or even reversed (e.g., Epsilon). In sum, there were similarities and significant differences across the case firms in the manner in which they developed their innovation capabilities, which involved qualitative transformations, truncations and reversals.

4.2 The role of learning mechanisms in the case firms' innovation capability-building paths

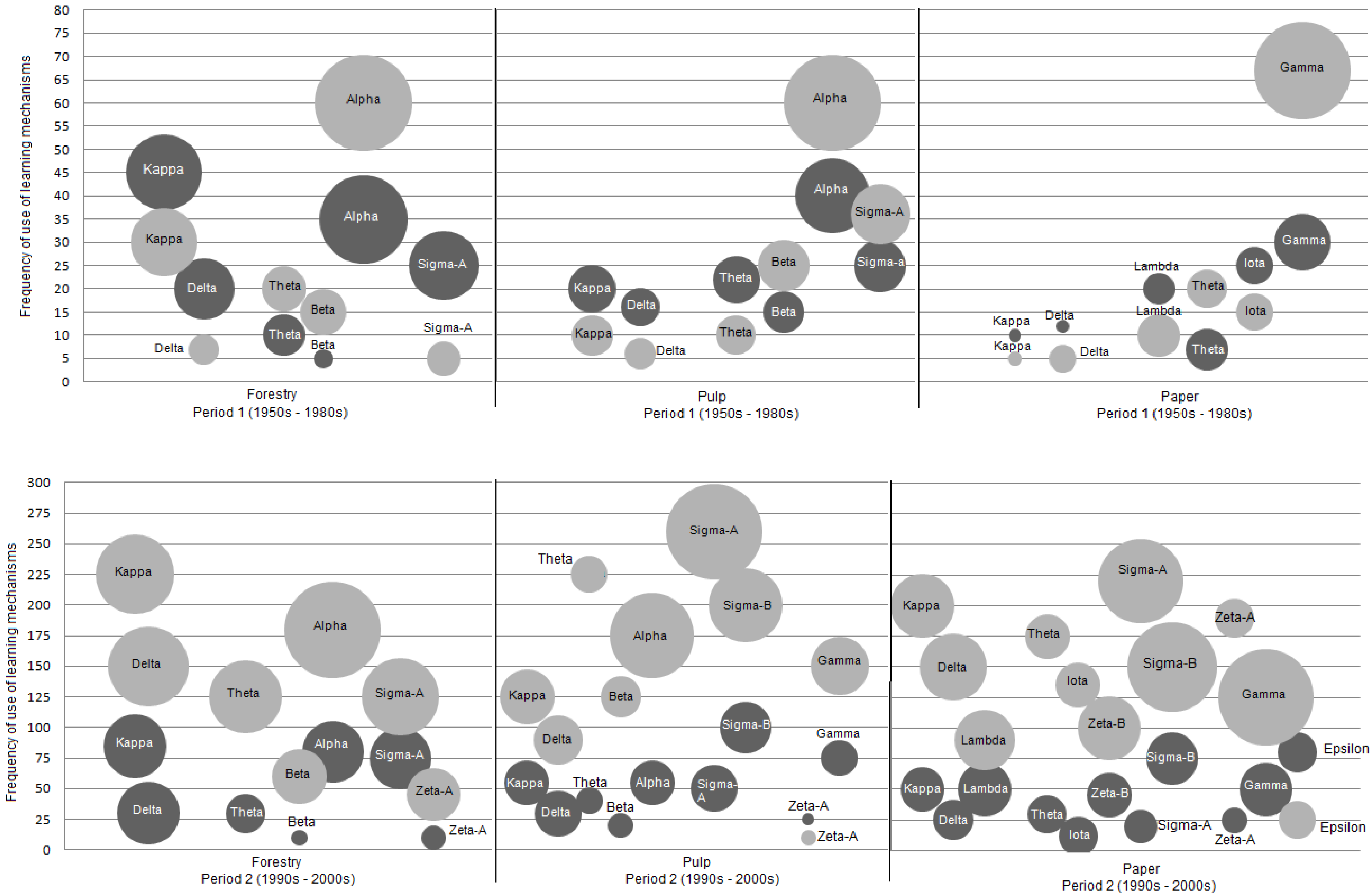
In this section, we examine how the underlying learning mechanisms have affected the differences and similarities in innovation capability-building paths across the studied firms. The presentation of the evidence is organized around two sub-periods (1950-1989 and 1990-2010) because this paper seeks to capture changes across and within firms in their learning processes over time and these two sub-periods are related to two major phases of industrialization in Brazil, the import substitution industrialization phase (ISI) and the trade liberalization phase. First, we examine the evolution of the frequency of use of both external and internal learning mechanisms in the case firms. Second, we examine the extent of changes in the quality of learning mechanisms used by the case firms across the two sub-periods. Third, we explore the extent to which specific learning mechanisms were more conducive to the attainment of particular levels of innovation capabilities in the case firms.

4.2.1 Evolution of frequency of use of learning mechanisms in the case firms

Figure 2 represents the evolution of intensity of use of learning mechanisms in the case firms. As indicated in Figure 2, most firms have increased the frequency of use of both external and internal learning mechanisms over time, especially during the period 1990-2000s in relation to the 1950-1980s period. Indeed, some firms increased substantially the frequency of learning mechanisms during the 1990-2000speriod indicating their efforts to strengthen their innovation capabilities to cope with the new institutional and economic conditions that emerged during the early 1990s.

However, other firms have kept the frequency of their learning mechanisms relatively unchanged across the two time periods. Evidence from Figure 2 in association with that of Table 4 suggests that firms that systematically increased the frequency of use of both external and internal learning mechanisms are those that have accumulated higher levels of innovation capabilities, especially at advanced and world-leading levels. However, this finding does not apply for all cases (e.g., Gamma). The observation suggests that an increase in the frequency of learning mechanisms may be necessary for the attainment of higher levels of innovation capabilities, although it is not sufficient. It seems that deliberate changes in the quality of each learning mechanism seem to be perhaps even more important, as explored below.

Figure 2. Evolution of use of external and internal learning mechanisms in the case firms



Keys: External learning mechanisms (ELM) Internal learning mechanisms (ILM)

Source: Derived from the empirical study.*Note:*Because we do not have a third numerical variable, this graph is used in a limited way for the purpose of representing the evolution of learning mechanisms.

4.2.2 Changes in the quality of learning mechanisms in the case firms over time

In this section we examine the changes in the quality of learning mechanisms which were used in the case firms (forestry, pulp and paper). The results are shown in Tables 5 to 7.To achieve these results, we first tested for any statistically significant differences between the means of the scores awarded to the external and internal learning mechanisms by each firm over time. The means of frequency of learning mechanisms were tested using a single-factor ANOVA. We considered the nature of each learning mechanism by separately testing both external and internal learning mechanisms for each firm across the two sub-periods. In these tests, the dependent variable was the number of external and internal learning mechanisms, and the factors being tested were the sub-periods (1950-1980s and 1990-2000s). The numbers in each cell represent the average number of each learning mechanism, by firm, within each sub-period.

The evidence in Tables 5 to 7 suggests a change in relative the importance of some learning mechanisms within each firm over time. Specifically, when we consider this evidence with the findings in Section 4.1 of levels of innovation capabilities developed by each firm, we observe that, as some firms developed higher levels of innovation capabilities (approached advanced to world-leading levels) there was a significant change in the nature and frequency of use of external and internal learning mechanisms. The highest intensity of changes was found in forestry, followed by pulp and then paper. Below we provide some qualitative evidence related to this issue.

Table 5. Results of ANOVA test showing degrees of changes in the use of learning mechanisms within *forestry* firms over time

Learning mechanisms	Alpha		Beta		Delta		Theta		Kappa		Sigma-A	
	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010
ELM-1	4.2	18.8	0.0	19.2	0.0	14.4	2.3	6.4	1.6	11.8	0.5	11.6
	0.001***		0.000***		0.001***		0.000***		0.000***		0.013**	
ELM-2	8.6	17.4	4.4	8.6	1.5	13.8	2.3	29.6	2.3	17.0	1.0	15.6
	0.056*		0.034**		0.001***		0.010**		0.003***		0.101	
ELM-3	11.6	16.8	0.4	2.0	0.9	9.6	1.3	5.4	0.5	3.2	0.0	2.6
	0.578		0.000***		0.000***		0.001***		0.004***		0.240	
ELM-4	5.4	26.0	0.0	1.4	0.0	15.6	0.5	4.8	2.0	13.4	3.0	11.8
	0.001***		0.008***		0.000***		0.005***		0.000***		0.030**	
ELM-5	0.0	23.0	0.0	0.0	0.0	18.2	0.0	22.2	0.9	7.6	0.0	2.4
	0.001***		-		0.005***		0.000***		0.001***		0.576	
ELM-6	8.6	14.2	3.4	6.0	1.1	1.8	1.9	9.4	3.0	13.6	0.0	12.0
	0.081*		0.100		0.742		0.000***		0.000***		0.026**	
ELM-7	0.0	1.2	0.0	0.0	0.3	0.4	0.0	0.4	0.6	3.0	0.0	2.0
	0.040**		-		0.695		0.220		0.000***		-	
ELM-8	0.8	1.0	0.6	1.0	0.1	0.2	0.0	0.0	0.4	1.8	0.5	1.0
	0.347		0.141		0.742		-		0.003***		0.117	
ELM-9	0.0	28.4	0.0	15.4	0.0	25.6	0.0	16.8	7.5	27.8	0.0	30.4
	0.000***		0.007***		0.000***		0.001***		0.001***		0.022**	
ELM-10	0.0	20.8	0.0	0.0	0.0	17.0	0.0	0.0	0.0	14.8	0.0	18.4
	0.004***		-		0.001***		-		0.000***		0.020**	
ILM-1	4.8	18.0	0.4	1.0	5.0	18.8	2.6	8.0	6.6	21.0	6.0	18.8
	0.000***		0.040**		0.002***		0.001***		0.000***		0.016**	
ILM-2	8.6	17.8	0.8	3.0	3.5	18.4	1.4	7.2	6.6	17.2	0.0	16.0
	0.010**		0.002***		0.001***		0.000***		0.001***		0.000***	
ILM-3	9.6	18.8	0.4	1.0	4.1	20.0	0.5	7.0	5.0	18.0	7.5	18.0
	0.011**		0.040**		0.000***		0.000***		0.001***		0.068*	
ILM-4	11.4	16.0	0.0	0.0	2.9	14.4	2.8	5.8	5.9	17.0	6.5	16.2
	0.152		-		0.001***		0.005***		0.010**		0.070*	

Notes:*p-value < 0.10; ** p-value < 0.05; *** p-value < 0.01. Each cell contains the average number of learning mechanisms. Zeta-A, Gamma, and Sigma-B were not included because they started up in the late-1980s and 1990.

Table 6. Results of ANOVA tests showing degrees of changes in the use of learning mechanisms within *pulp* firms over time

Learning mechanisms	Alpha		Beta		Delta		Theta		Kappa		Sigma-A	
	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010
ELM-1	5.0	16.4	0.3	4.6	1.3	9.4	2.0	3.4	2.1	8.6	0.7	29.6
	0.002***		0.014**		0.000***		0.018**		0.001***		0.018**	
ELM-2	8.7	26.8	1.8	9.0	1.5	17.6	2.5	6.4	2.9	15.8	1.7	28.4
	0.002***		0.001***		0.000***		0.058*		0.004***		0.076*	
ELM-3	7.0	18.8	0.8	1.8	0.5	2.4	0.0	0.8	0.0	1.4	0.3	10.6
	0.001***		0.122		0.001***		0.010**		0.061*		0.003***	
ELM-4	5.3	10.6	2.3	4.4	0.0	7.8	1.5	3.2	0.9	9.0	1.0	16.8
	0.037**		0.020**		0.001***		0.114		0.000***		0.081*	
ELM-5	0.0	0.0	0.0	0.0	0.0	0.8	0.0	1.0	0.0	2.8	0.0	57.2
	-		-		0.220		0.407		0.061*		0.115	
ELM-6	6.0	8.0	4.0	9.0	1.1	6.0	3.0	4.0	2.0	10.0	0.7	4.6
	0.055*		0.000***		0.005***		0.292		0.000***		0.356	
ELM-7	2.0	5.0	3.8	5.0	0.3	1.8	0.0	0.0	0.8	2.0	0.0	2.4
	0.036**		0.100		0.000***		-		0.022**		0.276	
ELM-8	0.0	0.0	0.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-		0.292		-		-		-		-	
ELM-9	12.3	60.2	0.8	9.0	0.6	13.0	0.0	11.6	0.8	16.8	10.0	53.8
	0.000***		0.000***		0.000***		0.000***		0.000***		0.000***	
ELM-10	8.0	46.0	0.8	2.2	0.1	6.6	0.0	6.6	0.4	11.8	6.0	45.8
	0.001***		0.019**		0.002***		0.001***		0.000***		0.000***	
ILM-1	11.7	17.0	0.0	0.0	1.4	9.0	4.0	5.2	3.9	11.8	1.7	10.4
	0.052*		-		0.000***		0.068*		0.008***		0.001***	
ILM-2	7.0	12.4	4.0	7.2	2.6	17.2	3.0	5.4	1.5	13.0	4.7	17.4
	0.004***		0.023**		0.000***		0.010**		0.000***		0.001***	
ILM-3	8.0	15.6	1.8	5.2	2.6	17.6	1.0	2.4	3.6	16.4	5.3	18.6
	0.009***		0.001***		0.000***		0.111		0.002***		0.017**	
ILM-4	5.3	9.4	3.8	5.0	2.0	13.4	5.0	5.8	4.0	12.2	4.0	13.8
	0.091*		0.292		0.001***		0.010**		0.013**		0.004***	

Notes:**p*-value < 0.10; ** *p*-value < 0.05; *** *p*-value < 0.01; Each cell contains the average number of learning mechanisms. Zeta-A is not included because it started up in 1990.

Table 7. Results of ANOVA test showing degrees of changes in the use of learning mechanisms within *paper* firms over time

Learning mechanisms	Gamma		Delta		Zeta-B		Theta		Iota		Kappa		Lambda	
	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010	1950-89	1990-2010
ELM-1	13.0	13.0	0.0	1.0	3.0	3.4	2.0	3.4	0.7	2.8	0.3	3.0	0.0	0.4
	-		-		0.541		0.018**		0.059*		0.004***		0.193	
ELM-2	9.8	20.0	0.8	8.2	2.0	9.6	2.5	6.4	1.7	1.8	0.4	10.6	1.5	15.6
	0.000***		0.001***		0.000***		0.014**		0.913		0.066*		0.000***	
ELM-3	8.3	9.0	0.0	3.4	0.0	0.0	0.0	0.8	0.0	2.0	0.1	3.0	0.0	0.6
	0.104		0.001***		-		0.010**		0.281		0.090*		0.068*	
ELM-4	13.0	28.4	0.0	0.0	1.0	1.2	1.5	3.2	2.0	6.8	0.0	4.8	3.0	6.0
	0.000***		-		0.838		0.114		0.088*		0.019**		0.089*	
ELM-5	0.0	3.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.8	0.0	1.2	0.0	3.0
	0.000***		0.220		0.605		-		0.343		0.057*		0.000***	
ELM-6	20.0	20.0	3.3	10.6	13.0	14.8	3.0	4.0	6.0	6.4	0.1	2.2	6.0	10.0
	-		0.002***		0.021**		0.292		0.267		0.049**		0.049**	
ELM-7	6.0	6.6	0.0	0.0	5.0	7.0	0.0	0.0	0.0	0.2	0.0	0.8	3.5	7.0
	0.024**		-		-		-		0.482		0.018**		0.020**	
ELM-8	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-		-		-		-		-		-		-	
ELM-9	0.7	16.0	1.0	20.4	0.0	13.6	2.0	21.0	0.0	5.0	0.8	21.4	0.0	3.8
	0.000***		0.000***		0.037**		0.000***		0.134		0.000***		0.001***	
ELM-10	0.7	1.0	0.8	14.2	0.0	0.0	0.5	6.8	0.0	0.0	0.0	5.0	0.0	0.0
	0.186		0.000***		-		0.012**		-		0.000***		-	
ILM-1	12.0	12.0	0.0	0.0	8.0	9.8	4.0	5.2	4.0	4.6	0.4	4.8	0.5	12.0
	-		-		0.276		0.068		0.304		0.008***		0.000***	
ILM-2	5.7	8.0	1.0	5.2	5.0	5.0	3.0	5.4	3.0	6.4	0.3	5.0	2.5	9.0
	0.011*		0.000***		-		0.010**		0.095*		0.023**		0.001***	
ILM-3	5.8	9.8	0.0	0.6	1.0	4.8	1.0	2.4	1.3	2.8	0.0	4.2	2.0	11.0
	0.000***		0.009***		0.437		0.111		0.349		0.009***		0.000***	
ILM-4	0.7	6.4	0.4	15.0	3.0	6.2	5.0	5.8	2.0	5.4	0.5	10.8	2.5	6.0
	0.000***		0.000***		0.178		0.010**		0.169		0.000***		0.028**	

Note:**p*-value < 0.10; ** *p*-value < 0.05; *** *p*-value < 0.01; Each cell contains the average number of learning mechanisms. Zeta-A, Gamma, Sigma-A, Sigma-B were not included because they started up in the late-1980s and 1990. Although Epsilon started up in the 1950s, it is studied herein since the 1990s.

During the first sub-period (1950-1980s), Brazil's industry worked under the ISI policy, which began during the early 1950s. Strong emphasis was given to basic industries and inputs, among them forestry and pulp and paper. Government agencies were created to support the development agenda, e.g., the National Research Council (CNPq), the Agency for Post-graduate Training (CAPES) dedicated to support research and human capital formation. Additionally, the Forestry Law (of 1966), which provided tax incentives for firms that developed planted forestry based on eucalyptus, contributed to the expansion of the forest bases needed for new pulp and paper mills. Under that ISI policy regime some firms took pro-active actions related to investments in learning for innovation capability building, whereas others were more passive.

For example, as early as the mid-1950s, Kappa took the lead in using learning mechanisms to acquire knowledge to develop research capabilities to produce paper from eucalyptus. At that time, Brazil lacked universities that could support the firm's research ambitions. Thus, Kappa's leadership developed links with the University of Florida at Gainesville (U.S.) to conduct experiments. From 1955 to 1962, Kappa's researchers conductedpersistentinvestigations, and by the end of the sixth year, their research eventually confirmed that it was possible to obtain good quality paper using 100 per cent eucalyptus pulp. In 1962, Kappa began to manufacture paper made from eucalyptus on a large-scale from its unit in São Paulo.

After its inception in the 1970s, Alpha differed significantly from other firms by using external learning mechanisms at a moderate frequency and, to some extent, a relatively moderate frequency of internal learning mechanisms in forestry. Kappa and Delta also used similar types of learning mechanisms less often than Alpha, and Kappa used more external learning mechanisms than Delta. Beta and Theta presented a lower learning mechanism score compared with other firms, except Sigma-A, which, starting in the 1980s, had a high internal learning mechanism score, especially for ILM-3 and ILM-4. In the other firms, there was a predominance of low scores for external and internal learning mechanisms, except for Beta and Sigma-A, which used some external learning mechanisms with a moderate frequency and internal learning mechanisms with a low frequency. In contrast to forestry, in the paper business, there was a higher score for external and internal learning mechanisms, especially in firms such as Gamma, followed by Theta, Iota and Lambda. Although Kappa is a paper producer, its learning efforts were more concentrated on forestry activities.

In the second sub-period (1990-2000s), the new economic and institutional conditions that emerged from the early 1990s, namely the trade liberalization, forced firms in Brazil to review their innovation strategies to confront global competition. There was, in general, a substantial change in the learning mechanisms of firms in the forestry, pulp and paper businesses characterized by an increase in the scores for external *and* internal learning mechanisms compared with the 1950-1980speriod. We have captured nuanced differences and similarities among the firms' learning mechanisms with varied impacts on their innovation capability building paths.

In forestry, Alpha again stood out, using external *and* internal learning mechanisms more often than it did in the 1950-1980s, although its intensity of use of some external learning mechanisms was similar to that of Delta, Kappa, Theta and Sigma-A. Kappa and Sigma-A also increased the frequency with which they used external and internal learning mechanisms, but unlike Alpha, they increased the frequency of internal learning mechanisms more than that of external learning mechanisms, most likely because they needed to accelerate the development of world-leading innovation capabilities during the 1990s and 2000s. In the forestry and pulp activities, specifically in the firms such as Alpha, Kappa, Delta, and Beta, there was a significant increase in the use of most external learning mechanisms, particularly research-based learning (ELM-9 to ELM-11), although in Theta, the changes in these latter mechanisms were not dramatic. In these firms, there also was significant increase in the use of internal learning mechanisms in the 1990-2000speriod compared with the 1950-1980s period indicating the firms' increased efforts to assimilate the externally acquired knowledge and convert it into the ability to innovate.

Additionally, during the 1990-200s period pulp firms such as Alpha and Sigma-A substantially increased the scores for external and internal learning mechanisms compared with the 1950-1980s period and distinguished themselves from other firms in the frequency of use of these learning mechanisms. Sigma-A also implemented similar strategies in the paper business. Similarly, Kappa also increased its use of external learning mechanisms in pulp and paper compared with the 1950-1980s, although with a less intensity compared with Alpha. However, Kappa strongly emphasized the internal learning mechanisms in the pulp and paper businesses, suggesting its intension of accelerate its process of developing innovation capabilities at advanced and world-leading levels during the 1990-2000s compared with the 1950-1980s. A similar action was taken by Gamma, although with much less emphasis on research-based external learning mechanisms and internal learning mechanisms when compared with Sigma-A, Kappa and Delta. Indeed, Delta also increased its use of external learning mechanisms in both the pulp and paper business lines during the 1990s compared with the previous period, although the firm placed greater emphasis on upgrading the research-based external learning mechanisms (ELM-9 and ELM10) and internal learning mechanisms.

In the paper activities, some firms stood out in the use of internal learning mechanisms, especially Delta and Kappa in which there also was a higher intensity of the use of research-based external learning mechanisms; in these firms, including Lambda, there were also significant changes in the frequency of use and the quality of the internal learning mechanisms (ILM-2 to ILM-4) in the 1990-2000scompared with the 1950-1980s period. Although Gamma used both external and internal learning mechanisms often during both periods, its changes in the use of these learning mechanisms differed from Delta and Kappa in the intensity and quality. This pattern of change of learning in Gamma seems to explain its achievement, at a relatively fast pace, of advanced innovation capability (14 years), although not at world-leading levels like Delta and Kappa. Indeed, Gamma's relative low importance to upgrade the quality of some learning mechanisms explains this capability level attained by the firm, despite its substantial increase in the overall frequency of learning mechanisms in the 1990-2000s period in relation to the 1950-1980s period.

Specifically, for research-based learning mechanisms, some firms sought to re-organize their research centres on the basis of more specialized and commercially oriented activities to sustain their innovation capabilities. They also realized the importance of partnerships to achieve this goal. For example, in 2002, Sigma-A and Sigma-B merged their R&D units into the Centre for Pulp Technological Development to accelerate the achievement of research outcomes. In 2005, this unit designed software, based on a complex set of equations, to calculate the economic value of a clone, allowing the firm to choose the best clone for specific sites. In 2002, papermaker Delta reviewed and re-organized its research centre not only to deepen its research into new genetic material but also to improve the development of products and processes activities. Kappa, on the other hand, regained its innovation drive in 2006, after a period of unfocused strategy during the 1990s due to internal management problems. Its new top management emphasized research-based innovation, especially in forestry, as a key driver of Kappa's international leadership.

One of the remarkable forestry research initiatives of the 2000s was the emergence of the Genolyptus Project – Brazilian Network of Eucalyptus Genomics Research (2002-2008). Sponsored by one of the innovation funds from the Ministry of Science and Technology, this large research project involved 13 firms and seven universities, under the coordination of the

Brazilian Agricultural Research Corporation (EMBRAPA). Genolyptus gathered a large amount of genomic information to further the understanding of eucalyptus gene variation. One of the novelties of Genolyptuswas a focus on wood disease resistance and its implications for innovation, productivity increase and the international competitiveness of Brazil’s pulp and paper industries (Grattapaglia, 2004; Grattapaglia and Kirst, 2008). As a result of this successful project, Brazil became one of the few countries to undertake cutting-edge eucalyptus genomic research based on a nation-wide biotechnology network.The case firms that were more actively involved with Genolyptus (e.g., Alpha, Kappa, Delta, Theta, Sigma-A and Sigma-B) used extensively external learning mechanisms ELM-9 to ELM-11 to undertake the project’s knowledge collaborations in association with internal learning mechanisms ILM-1 to ILM-4 to assimilate and implement the wealth of knowledge generated by the project. These learning efforts played a substantial role in strengthening these firms’ world-leading innovation capabilities, especially in forestry, with positive reflections on pulp and paper.

4.2.3Learning mechanisms and the development of specific levels of innovation capability

We sought to examine whether there were significant differences and similarities among the learning mechanisms in the frequency of their use and their quality *within* each firm within each time period in association with the levels of innovation capability that were developed by the firms. The objective was to examine whether there were differences and similarities in how the learning mechanisms affected the attainment of particular innovation capability levels. We first tested for any statistically significant differences between the means of the scores assigned to the external and internal learning mechanisms by the firms that accumulated the same innovation capability level. The means of frequency of learning mechanisms were tested using a single-factor ANOVA, following by the Duncan test. We considered the learning mechanisms together and independently on whether they were external or internal. In these tests, the dependent variable was the number of learning mechanisms used by firms that had accumulated the same capability level, and the factor being tested was the learning mechanism (see Table 8). The numbers in each cell represent the means of frequency of use of each learning mechanism by firms, which were grouped according to the levels of innovation capability that they had accumulated within each sub-period. All these tests were performed separately for each sub-period (1950-1980s and 1990-2000s) and for each level of innovation capability.

The evidence in Table 8 suggests that during the 1950-1980speriod, the achievement of a world-leading level of innovation capability, especially in forestry and pulp, was associated with an intense use of external learning mechanisms, such as local and overseas education and training and organizational arrangements for external knowledge acquisition, in association with internal learning mechanisms. During the 1990-2000speriod, the achievement of this capability level involved not only intensification of the use of learning mechanisms that had been used in the first period, but also an additional emphasis on other types of external learning mechanisms, especially research-based ones, with a more intense use of internal learning mechanisms. Specifically, some learning mechanisms, or a combination of them, were more effective than others in contributing to the attainment of particular innovation capability levels.

For example, a progressive change to a combination of increased intensity of external learning mechanisms ELM-1 to ELM-6, research-based mechanisms such as ELM-9 and ELM-11 (especially during the second period), and internal learning mechanisms ILM-1 to ILM-4 proved essential for the attainment and sustaining of world-leading innovation capability levels over time, especially in forestry and pulp. A combination of several external learning mechanisms (ELM-2 and ELM-3, during the first period, along with ELM-9 during the second period) and internal learning mechanisms (ILM-1 and ILM-4)was effective for achieving intermediate innovation capability levels in forestry and pulp, especially during the second period.

Table 8. Results of ANOVA and Duncan tests showing degrees of association between learning mechanisms and the attainment of specific innovation capability levels

Innovation capability levels / Learning mechanisms	1950-1980s								1990-2000s								
	Forestry		Pulp			Paper			Forestry			Pulp			Paper		
	Advanced to world-leading	Intermediate to Advanced	Advanced to world leading	Intermediate to Advanced	Basic to Intermediate	Advanced to world-leading	Intermediate to Advanced	Basic to Intermediate	Advanced to world-leading	Intermediate to Advanced	Basic to Intermediate	Advanced to world leading	Intermediate to advanced	Basic to Intermediate	Advanced to world-leading	Intermediate to Advanced	Basic to Intermediate
ELM-1	3	0.6	3	2.6	2	0.2	8.1	0.3	12.6	14.3	16.8	17.4	8.7	1.7	4.8	6.6	1.8
ELM-2	4.7	2.3	4.8	4.3	2.5	1	6.4	1.6	23.5	13.8	7.2	25.2	11.9	4.7	13.7	12	7.7
ELM-3	5.2	0.6	2.9	0.4	0	0.1	4.5	0	11.1	4.4	3.4	11.1	4	0.4	7.7	3.3	1
ELM-4	2.4	1	3.2	4.6	3	3	13.2	6	15.4	10.6	2.8	8.9	13	2.0	10.2	12.9	5.6
ELM-5	0	0.1	0.9	3	0	0	3.7	2	19.4	4.2	0	3	4.5	0	2.6	4.5	2.7
ELM-6	4.5	2.2	2.6	2.3	1.5	0	7.7	2.6	11.8	8.4	7	13.8	11	1.6	10.5	10.9	4.3
ELM-7	0	0.3	0	0	0	0	0	0	0.8	1.4	0	10.8	1.5	0.5	0	1.3	1.2
ELM-8	0.3	0.4	0	0	0	0	0	0	0.5	1	2.4	6.8	0.5	0	0.5	0	0.1
ELM-9	0	2.6	8	1.3	0	1.6	1.1	0	22.6	24.8	11.2	38.6	11.6	7.6	19.8	16.9	3.4
ELM-10	0	0	4.8	0.9	0	0.7	0.5	0	10.4	12.6	0	28.4	5	3.3	6	2.6	0.1
ILM-1	3.4	4.6	5.7	4.4	4	0.3	8.7	2	13	14.9	2.2	13.7	7.9	2.8	4	9	5.7
ILM-2	4.2	3.7	6.2	4.0	3	1.1	4.6	2.7	12.5	13.7	3	16.1	9.4	3.5	5.7	6.1	5.7
ILM-3	4	3.9	6.8	5.1	1	0	3.6	1.7	12.9	14.3	3.4	17.6	10.5	1.6	5.2	5.7	5.5
ILM-4	6.1	3.6	4.9	6.7	5	0.8	2.5	2.3	10.9	11.9	1.8	13.1	7.7	3.5	8.9	6.1	4.7
F(df1;df2)	2.857 (13;167)	4.737 (13;308)	3.006 (13;112)	3.417 (13;84)	20.423 (13;42)	3.379 (13;112)	10.388 (13;140)	6.839 (13;84)	5.22 (13;126)	15.116 (13;266)	26.411 (13;56)	11.793 (13;266)	10.954 (13;196)	6.026 (13;126)	13.856 (13;266)	12.94 (13;196)	11.479 (13;266)
Sig	0.001***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***

Note: Each cell contains the average number of learning mechanisms in the period 1950-2010.(***)*p*-value < 0.01; Results of Duncan's test grouping for the relationship between specific learning mechanisms and levels of innovation capability.

High Moderate Low

The external learning mechanisms ELM-2, ELM-4 and ELM-6 combined with internal learning mechanisms ILM-1 to ILM-3, were equally significant to the achievement of an intermediate level of innovation capability in paper. The fact that the firms that achieved world-leading innovation capability in forestry and pulp are also active in paper (except in Alpha, which does not operate the paper business), seems to suggest that they took advantage of the knowledge accumulated in the upstream forestry and pulp businesses, to leverage their innovation capability in paper.

5. Discussion and Theoretical Implications

The aim of this paper was to advance the understanding of how both internal and external learning mechanisms affect differences and similarities among latecomer firms in developing innovation capabilities. This relationship was empirically examined in a set of 13 natural resource-processing industries based on long-term evidence derived from original fieldwork. In contrast with most existing studies, this paper has proxied innovative technological capabilities based on the novelty and complexity of activities that the firm is able to undertake at different points in time. The study found differences and commonalities among the firms in the manner in which they developed their innovation capabilities which, in turn, reflected the way in which each firm managed its external and internal learning mechanisms over time. Such an approach has hardly been explored in the related literatures. Below, we discuss the findings about the learning mechanisms underlying the firms' innovation capability-building paths, which provide answers to the paper's research question, and the correspondent theoretical implications.

First, our findings indicate that the firms that combined the use of external and internal learning mechanisms with increased *intensity* and *quality* achieved higher innovation capability levels than those firms that used the learning mechanisms with limited frequency and unchanged quality over time. Indeed, there was a highly significant *change in the relative importance of both external and internal learning mechanisms* as some firms' capabilities approached the world-leading level. However, in others cases, the changes were moderately significant and, in additional cases, such changes were not significant, leading to a limited accumulation of innovation capabilities.

Specifically, by capturing important nuances and intricacies of the changing nature of external and internal learning mechanisms underlying innovation capability-building paths in latecomer firms, this study expands our understanding of the role of firm-level learning as a primary source of innovation capability building. The study shows that differences and similarities among latecomer firms, in the same industrial sector, in the manner in which they develop their innovation capabilities and, consequently, become world-leading innovators or remain innovation followers or even laggards, is largely explained by the differences and similarities not only in terms of increased frequency of use but, mainly, in terms of changes over time in the quality of both external and internal learning mechanisms. These inter-firm differences and similarities in innovation capability-building depend on ways in which each firm changes the relative importance of external and internal learning mechanisms over time.

Second, our findings suggest that some deliberate combinations of external and internal learning mechanisms were associated with the attainment of particular levels of innovation capabilities. It is noteworthy that some form of reverse causality was apparent: those firms that developed more effective learning mechanisms (e.g., Alpha, Sigma-A, Sigma-B, Delta) seem to have done so because they simultaneously accumulated high levels of innovative capability. This finding indicates the importance of the *effectiveness of learning mechanisms* for innovation capability-building in latecomer firms, an issue that has been scarcely researched in the related literatures.

Third, our findings support existing studies based on firms in advanced economies that emphasize the importance of both external and internal learning mechanisms to innovation capability building. However, by drawing on evidence from a set of latecomer multi-divisional firms, this paper extends beyond these studies by exploring how the changing frequency and quality of an integrated process of learning (involving several types of both external and internal learning mechanisms) affect, in different ways, the building of innovation capability. Consequently, our study indicates that the recent approach to learning based on the 'open learning process', which emphasizes the importance of external sources of knowledge to firms' innovation performance and the post-Chandlerian types of learning, seems to be either limited and/or premature in explaining the differences and similarities among firms in innovation capability-building, at least in the context of latecomer firms.

6. Implications for Corporate Management

The results have some implications for managers seeking to develop innovation capability to achieve and sustain international competitive performance. To attain that goal, managers should deliberately pursue constant increases in the frequency and quality of multiple learning mechanisms for five reasons. First, the external and internal learning mechanisms that contribute to the attainment of one capability level are not sufficient to achieve the subsequent (higher) level. Second, maintaining the frequency and quality of learning mechanisms is likely to constrain the firm's accumulation of progressively higher levels of innovation capability. Third, internal and external learning mechanisms differ in their contribution to the accumulation of specific types and levels of innovation capability.

Fourth, relying on a few learning mechanism, no matter how powerful they seem to be, is unlikely to yield effective and sustained accumulation of innovation capability. Fifth, the achievement and sustaining of the capability for world-leading innovation involves engaging in audacious and risky learning mechanisms at the early stages of the capability development process. Thus, managers should explore and combine knowledge complementarities across different internal and external learning mechanisms *over time*. However, learning, while as a powerful source of innovation capabilities, is neither automatic nor linear. Managers must be prepared to find difficulties in implementing ambitious learning mechanisms. The implementation of such learning mechanisms may be limited by firms' strategic inconsistencies and idiosyncrasies and also by lack of support from top management.

Consequently, managers should recognize the importance of negotiating the allocation of resources for learning to accumulate innovation capability.

7. Conclusion

This study indicates that if latecomer firms make limited efforts to use and deliberately change the intensity and, mainly, the quality of *both* external and internal learning mechanisms over time, they will deepen their innovative capabilities slowly and will tend to remain locked into forms of ‘follower’ innovation rather than innovating as leaders. Therefore, by drawing together concepts and insights from the literatures on strategic management, organizational learning, and innovation in both advanced and developing/emerging economies, this study furthers our empirical and theoretical understanding of learning as a key contributor to firms’ innovation capability building.

First, this paper advances our understanding of the *process* by which latecomer firms accumulate (or fail to accumulate) innovation capabilities at world-leading level, by measuring this process on the basis of the accumulation of progressive levels of capability and the influence of the underlying learning mechanisms. Second, our study explores the nature of the firm-level learning process and how it enables or inhibits the accumulation innovation capabilities, especially in latecomer firms. By substantiating this analysis with first-hand and long-term evidence derived from extensive field research, our study adds texture to our understanding of the intricacies, nuances and dynamics of the learning process and how it affects differences and similarities among latecomer firms in innovation capability building. Third, our study contributes to broadening our perspective on how latecomer firms manage their knowledge sources to achieve (or fail to achieve) international competitive performance. Fourth, considering that latecomer firms normally begin operation at a low level of innovation capability (if at all), this paper contributes to a deepening of our understanding of the process of innovative capability development and technological catch-up of latecomer firms.

Future research should investigate the extent to which learning strategies in latecomer firms, but also in knowledge systems, change over time, in association with firms' paths of innovation capability building, as a result of changes in influencing firm-specific factors (e.g., leadership behaviour, firm strategy, norms and values) and changes in industry-level and economy-level factors (e.g. policy framework) and global-level factors affecting firms. Such kinds of analyses would generate meaningful explanations to latecomer firms' capability building processes.

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Appendix. Framework for examining learning strategies (expanded version)

EXTERNAL LEARNING MECHANISMS

ELM- 1: HIRING OF EXPERTISE
Hiring newly graduates from local universities
Hiring expertise for assessing production processes
Hiring expertise for adapting and improving technical, organizational and managerial processes
Hiring experienced engineers and researchers for leading special innovation projects
Hiring expertise for undertaking R&D activities
Hiring of experienced professionals from competitors
'Poaching' of experienced development engineers from other firms, perhaps from leaders in advanced economies;
Start-up and commissioning experts
Overseas technicians working in the firm

ELM-2: LOCAL EDUCATION AND TRAINING PROGRAMS
Generic education and training based on operational and technical subjects
Undergraduate programs
Post-graduate courses: specialization, master, doctorate
Advanced training programs for technical, organizational and managerial improvements with local training centres and/or universities
Active participation in scientific meetings (e.g. presentation of technical papers)

ELM-3: INTERNATIONAL EDUCATION AND TRAINING PROGRAMS
Post-graduate programs: specialization, master, doctorate
Advanced training programs for strengthening production capabilities in forestry and/or pulp and paper with international training centres and/or universities
Advanced technical training programs in international training centres and/or universities
Active participation in scientific meetings (e.g. presentation of technical papers)

ELM-4: ORGANIZATIONAL ARRANGEMENTS FOR EXTERNAL KNOWLEDGE ACQUISITION
Organizational arrangements such as policies, procedures, teams, specific technologies that can support the external knowledge acquisition processes

ELM- 5: LEARNING FROM TECHNICAL ASSISTANCE AND SPECIALIZED CONSULTING FIRMS
Knowledge acquisition on how to achieve specific certifications
Acquiring knowledge from highly-specialized consultants on how undertake specific technical and organizational innovations
Interactions with specialized consultants for project design and development
Knowledge acquisition in how to strengthen and renew production and operational capabilities
Learning to undertake advanced and/or world-leading activities

ELM-6: ACQUISITION OF CODIFIED KNOWLEDGE AS A BASIS FOR DIFFERENT INNOVATIVE ACTIVITIES
Search of patent documentation to identify specifications as a basis for innovation (e.g., data about impending out-of-patent products as a basis for engineering the necessary process);
Acquisition of design algorithms for undertaking process design and development;
Access to diverse sources of knowledge (articles, theses, books, standards, research reports).
Acquisition of and upgrading of specific knowledge bases (e.g. technical standards, patents, product specifications)

ELM-7: TRAINING WITH LOCAL AND FOREIGN SUPPLIERS
Training to increase efficiency of complex production activities
Training to introduce technical and organizational innovations
Interactions with local and foreign suppliers for project design and development
Technology seminars with customers

ELM-8: KNOWLEDGE-BASED INTERACTION WITH LEADING USERS
Knowledge exchange in problem-solving and problem-framing
Knowledge acquisition through joint project design and development
Learning by creating new marketing practices
Acquisition of full design details of products from customers, perhaps with process data as well, or the licensing of product designs from third parties

ELM-9: RESEARCH AND DEVELOPMENT-BASED INTERACTIONS WITH SUPPLIERS AND COMPETITORS
Learning through interaction with suppliers and competitors based advanced innovation projects (e.g. co-design, co-development, joint-R&D, pre-competitive research)

ELM-10: RESEARCH-BASED INTERACTIONS WITH LOCAL UNIVERSITIES AND RESEARCH INSTITUTES
Partnerships for development of new products
Interactive bases joint research with universities and research institutes

ELM-11: RESEARCH-BASED INTERACTION WITH INTERNATIONAL UNIVERSITIES AND RESEARCH INSTITUTES
Partnerships for development of new products
Interactive bases joint research with universities and research institutes

INTERNAL LEARNING MECHANISMS

ILM-1: VARIOUS KINDS OF TRAINING TO ACQUIRE AND DISSEMINATE INNOVATION RELATED-SKILLS
Training in routines of development new genetic material, development of new processes sequences in laboratory, development of new product
Internal training focused on quality systems improvement
Advanced tailored technical training to upgrade technical skills of specialized groups technicians , engineers, researchers, and managers (including on-the-job training, supervised training)
Advanced management training (cutting edge techniques for project and research management, process /product innovation)
Project and process software training
Systematic training related to various R&D activities

ILM-2: KNOWLEDGE ARTICULATION AND VARIOUS KINDS OF INTRA-FIRM COMMUNICATION
The 'socialization' of what may have been tacit or located only in isolated parts of the organization
Learning by doing activities with increasing levels of difficulties
Internal technical and management seminars to disseminate results of innovative experiment/projects
Reporting from external training
Communication through formal and informal meetings, workshops, seminars, video conferences, and social interactions
Collective learning through sessions of discussions, de-briefing of on-going projects and performance reviews
Learning by experimenting and testing in shop-floors, laboratories, forestry sites
ILM-3: KNOWLEDGE SHARING AND VARIOUS FORMS OF KNOWLEDGE ACQUISITION WITHIN THE FIRM
Multi-disciplinary teams to exchange knowledge to solve and/or frame problems within and across organizational areas
Cross-functional and multi-disciplinary teams for prototype development through 3D engineering
Communities of practices (real and virtual)
Dissemination of 'T' and 'A' skilled people and 'knowledge-bridging' individuals across organizational areas
Dissemination of specialists to framing and solve problems across functional areas
Exchange knowledge through internal network
Sharing of 3D models with suppliers, consultants and in-house experts through global engineering and co-current engineering
ILM-4: KNOWLEDGE CODIFICATION AND RELATED ORGANIZATIONAL ARRANGEMENTS
Team/group work to create material codification
Documentation of activities developed during the production process
Routinization of newly created processes in production systems, supporting units, and forestry fields
Standardization of the projects engineering practices
Documentation of administrative procedures (e.g., internal communications and memoranda)
Design, development and implementation of automation systems
Material specification and codification (e.g., engineering standards and codes; modular solutions for projects)
Norms and regulations (internal communication and memos)
Creation of technical and environmental procedures
Document control and technical contract management systems
Integration between operational and corporate systems
Arrangements related to organizational specialization in specific kinds of innovative activity, arrangements for integrating knowledge across different functional areas in the organization, and across different fields of specialization and also across the boundaries of the firm.

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